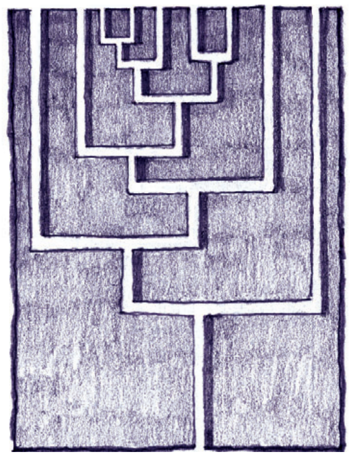
BIOLUMINESCENCE



BLINDED BY THE LIGHT – THE FANTASTIC FLASH OF THE CLUSTERWINK SNAIL

Bioluminescence, the biological production of light, is a breath-taking event to behold. Brilliant squid, elegant jellies and glowing fish use this strategy to attract mates, detect prey, camouflage themselves or deter predators. Extraordinary adaptations to transmit light are well characterized in open ocean species but are not well described in marine molluscs in other habitats. Although the intertidal, thumb nail-sized clusterwink snail, *Hinea brasiliana*, is known to be among these luminous creatures, the mechanism behind its light production was a mystery. Dimitri Deheyn and Nerida Wilson at the Scripps Institution of Oceanography (UCSD) set out to unravel these secrets, exposing an incredible, unique tactic behind the glow of this snail.

Deheyn and Wilson caught the tiny snails on the beaches of eastern Australia, where they cluster in groups among rocks. The duo transported their catch to the laboratory to quantify the snail's emitted light. First, they stimulated the snails to produce light using chemicals and, within seconds, the clusterwink emitted a radiant blue–green light from an area of its body incapable of extending beyond the shell. Next, they placed snails with other organisms from their habitat to find out what provoked the molluscs' light display. They found that the snails produced their highest light levels when they encountered species that they contacted frequently. To determine whether the clusterwink's light show could be mechanically stimulated, the team then placed the snails with actively swimming amphipods, providing ample opportunity for physical interaction. Although rare as a trigger of bioluminescence in other species, physical contact did trigger intense light displays from the snails.

As the source of light cannot extend beyond the snail's opaque, pigmented and calcified shell, the authors then characterized how the shell transmitted and diffused light. They found that despite its hardiness, the shell transmits most wavelengths of light, with the exception of the blue–green peak of the snail's bioluminescence. However, when blue–green light is shone into the shell (mimicking natural bioluminescence), it scatters to parts of the shell not directly exposed to the source, allowing regions of the shell that are not directly illuminated to glow. Deheyn and Wilson also found that the wavelength of the light is not altered by the pigment or opacity of the shell, in contrast to other bioluminescent organisms that do alter the light's colour. The shell also transmits light incredibly effectively for its thickness: 8 times higher than an equivalent commercially available diffuser. Although high transmittance is usually associated with low diffusion in materials, the shell's biomaterial retains a remarkable capacity to diffuse light. In fact, the blue–green glow projects over the entire shell, an area 10 times larger than that of commercial diffusers. The authors think that this remarkable property co-evolved with *H. brasiliana*'s luminous capacity as the shells of closely related non-bioluminescent species do not diffuse or transmit light.

This is the first account of a calcified structure that diffuses and enlarges biologically produced light, perhaps providing inspiration for the next generation of light-transmitting materials and optical devices. However, from the clusterwink's perspective, their shells provide an exceptional defence tactic: producing an intense and enlarged flash of light to deter predators while offering shelter to the resident within.

10.1242/jeb.049742

Deheyn, D. D. and Wilson, N. G. (2011). Bioluminescent signals spatially amplified by wavelength-specific diffusion through the shell of a marine snail. *Proc. R. Soc. Lond. B*, doi:10.1098/rspb.2010.2203.

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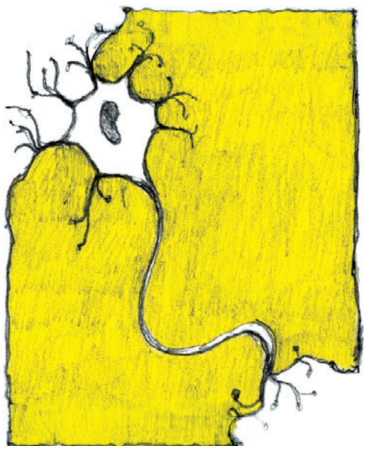
COMMUNICATION



SLEEPLESS NIGHTS LEAD TO MISCOMMUNICATION IN HONEY BEES

We all know by personal experience how important sleep is. If I don't sleep well, I'm cranky in the morning and tired and unproductive the rest of the day. One of the consequences of prolonged sleep deprivation is the deterioration of the capacity to communicate, in terms of both communicating ideas and understanding what others are trying to communicate to us. In the case of truly social animals such as the honeybee, social function heavily relies on the ability of the individuals to communicate with each other. Honeybee workers, for example, frequently report to their fellow nestmates about the direction and distance of foraging sources and potential nest sites. They do this by performing an interpretive 'waggle dance' in which they indicate the distance to the desired location by the duration of the waggle portion of the dance, and the direction to their destination by the angle of the dance with respect to the sun. As sleep is so important for communication in humans, could it be possible that bees also need their nightly rest to accurately communicate with their nestmates? This was the subject of research in a study recently published by Barret A. Klein and his colleagues at the University of Texas.

To deprive bees of their precious sleep, the scientists first devised a contraption that they suitably called the 'insominator'. The device consisted of columns of magnets that could be slid up and down the hive's frame. Then the researchers glued small disks made out of steel on the back of some of the bees. When the insominator glided over the hive, the magnets attracted the metal disks, jostling the bees and waking them if they had fallen asleep. The following day, after a long sleepless night for both the bees and the operator of the insominator, the bees went out for their daily foraging excursion. On their return, each bee performed its usual dance while Klein and his colleagues videotaped the events. From these videos, the group of researchers was able to study the variability in the duration and the angle of the dances and, therefore, determine the accuracy of the messages that the bees were trying to convey to their fellow workers.

As expected, the variability in the angle of the waggle was higher in the sleep-deprived bees than in bees that had been allowed to sleep through the night. These findings indicate that the bees' ability to accurately convey the direction of the foraging site had decreased after a night of sleep deprivation. On the other hand, the length of the waggle phase of the dance did not change with sleep deprivation; bees could still precisely tell their nestmates how far away the foraging site was. Klein and his colleagues propose that, perhaps, it is not as costly to signal this type of information.

The fact that a sleepless night impairs the bees' ability to accurately communicate the location of a food source to their nestmates has important implications about the evolution of sleep in social animals. Whether the errors in communication between insomniac bees are significant enough to guide bees to the wrong site, or whether fellow bees are able to find the site in spite of imprecise directions will be the subject of future research for Klein and the team. Either way, I'm too old to pull an all nighter … just keep that insominator away from me.

10.1242/jeb.049767

Klein, B. A., Klein, A., Wray, M. K., Mueller, U. G. and Seeley, T. D. (2010). Sleep deprivation impairs precision of waggle dance signaling in honey bees. *Proc. Natl. Acad. Sci. USA* **107**, 22705-22709.

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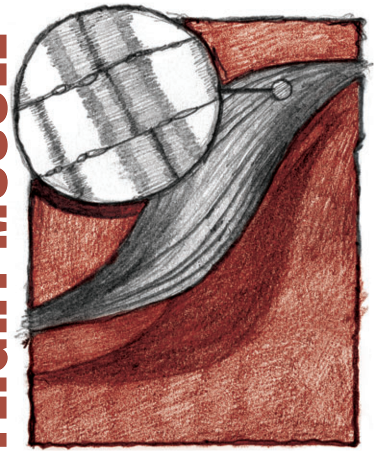
FLIGHT MUSCLE



MECHANISM FOR STRETCH ACTIVATION PROPOSED

Insects are among the most successful animals that have conquered air. As flying is energetically demanding, they have evolved ingenious ways to reduce the energetic costs of flight. Modern insects have developed indirect flight muscles with a remarkable property called 'stretch activation', where the contraction of the muscle is triggered by stretching. Since its discovery, scientists have looked for a mechanistic explanation for this phenomenon. In a recent paper published in *PNAS* a team of US scientists guided by Mike Reedy provides fascinating insights into the underlying mechanism by observing X-ray diffraction patterns of beating flight muscles.

The benefit of stretch activation is evident when we look at the anatomy of insect indirect flight muscles. They do not move the wings directly but change the shape of the elastic thorax, which translates into up and down movements of the wings. The muscles are organized in antagonistic pairs of longitudinal depressors and dorsoventral elevators. When the depressor contracts it stretches and activates the elevator, and *vice versa*, yielding freely oscillating muscle contractions and buzzing wings. But how can stretch activation be explained at the molecular level? In normal muscle fibers, muscular contractions, where actin and myosin filaments slide past each other, are triggered by increased levels of Ca^{2+}. In resting muscles, the interaction between actin and myosin is blocked by tropomyosin but, when a contraction is initiated, Ca^{2+} binds to a protein called troponin, which induces a conformational change in tropomyosin so that it no longer prevents myosin from binding to actin. However, insect flight muscles are special as a Ca^{2+} stimulus is still necessary to prime contraction but it alone is not sufficient to unlock the tropomyosin bar. So, what is the switch that is necessary to open the gate?

To answer this question, Reedy and his colleagues studied the flight muscles of the giant water bug *Lethocerus*, which is a convenient model system because the isolated muscle fibers oscillate for several hours. Using electron microscopy, they first found novel cross-bridges between actin and myosin filaments involving troponin, which they named troponin bridges. Then, in a remarkable experiment, the team exposed the oscillating muscle to a very intense beam of X-rays, and recorded the muscle's diffraction patterns as they varied in time with the muscular contractions.

The results of this experiment were stunning: an X-ray movie showing the movements of single molecules within the oscillating muscle fibers. As the scientists were able to assign single reflections to myosin heads, actin filaments, troponin and tropomyosin, they could measure their relative positions at any single moment of the contraction cycle. Based on these data they proposed a model in which the troponin bridges mechanically assist in pulling tropomyosin away and exposing the myosin binding sites on actin when the fibers are stretched. This mechanical signal transduction appears to act together with Ca^{2+} binding to troponin, to unlock the tropomyosin gate but leave it shut until stretch finally pushes it open.

Reedy and his colleagues propose a model explaining stretch activation by a lock-out release mechanism involving Ca^{2+} and the newly discovered troponin bridges. Stretch activation also plays a role in the mammalian heart muscle, where it is believed to assist in blood ejection from the ventricles. The molecular mechanism of this process is not completely understood, but maybe future work will also discover troponin bridges in the mammalian heart.

10.1242/jeb.049759

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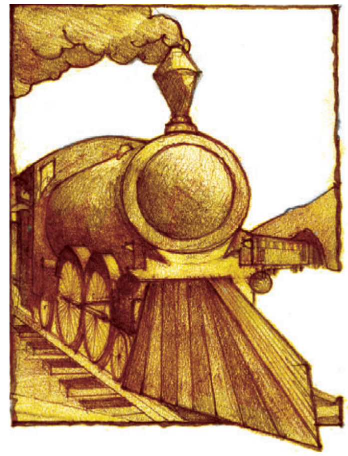
PROPULSION



PULSED WAKES ARE (SOMETIMES) BETTER THAN STEADY JETS

Do fish and jellyfish swim better than submarines? It depends a lot on what you mean by 'better'. Some people have argued that fish are more efficient than subs, meaning that they waste a smaller fraction of the total propulsive energy. Others have argued that efficiency isn't all that important; instead, it's just the total energy that matters, regardless of what fraction of it is wasted.

One major difference is that jellyfish and fish produce thrust in pulses, whereas propellers on submarines produce thrust more or less continuously.

There's good reason to suppose that pulsed propulsion (jellyfish) might be more efficient than steady jets (propellers). For example, pulses produce vortex rings, which tend to pull in extra fluid because of their rotation, resulting in a jet that's effectively larger than an equivalent steady jet. But pulses may also take more energy to produce.

Unfortunately, it's rather hard to compare a jellyfish with a sub. One is fast; the other is slow. One uses muscle; the other uses motors. The body shapes tend to be different. There are so many differences that it's hard to know whether the mode of propulsion makes any difference. But Lydia Ruiz, Robert Whittlesey and John Dabiri at the California Institute of Technology have recently developed a way to make a direct comparison. They built an ingenious submarine that can propel itself with pulses, kind of like a jellyfish, or with a continuous jet, like a normal sub. They carefully designed the device so that it always uses the same motor, the same transmission and the same body, whether it's pulsing or producing a steady jet.

The sub looks like a torpedo, with a ring of holes in the hull. A normal propeller sits inside and pulls fluid in through the holes and pushes it out through the back end. That's basically like a torpedo. The ingenious part is that inside the hull is an extra spinning ring that also has holes. When the holes in the inner ring align with the holes in the hull, then fluid comes into the hull and passes through the propeller, which pushes it out the back, resulting in a pulse of thrust. If the inner ring has very large holes, then fluid can reach the propeller almost all the time, resulting in a steady jet. If the inner ring has smaller holes, then fluid only reaches the propeller when the holes align. By swapping just that one inner ring, the group was able to convert a sub with a steady jet to one with a pulsed jet – and keep everything else the same, so that they could compare the performance.

Indeed, the group found that pulsed propulsion was almost always 20–40% more efficient than the baseline steady jet. At low pulse rates, though, the energy saved through increased efficiency didn't make up for the extra energy required to spin the ring to make the pulsed jet. But at high pulse rates, the group saw an overall energy saving.

So jellyfish, and maybe also fish or biomimetic submarines with flapping fins, may in fact swim better than subs, but only if they're clever about how they produce their pulses.

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